Egyptian Journal of Aquatic Research (2016) xxx, xxx–xxx

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Egyptian Journal of Aquatic Research

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FULL LENGTH ARTICLE

Water and sediment oil content spread in Dumai coastal waters, Riau Province, Indonesia

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Received 22 June 2016; revised 24 August 2016; accepted 25 August 2016

KEYWORDS

Anthropogenic;
Dumai;
Environment;
Oil;
Sediment;
Water

Abstract Dumai coastal water is one of coastal area that very active in Indonesia, since it has national and international shipping lanes. Furthermore along coastal waters of Dumai are locate various industries likely influencing coastal environmental water quality. The study aimed to examine oil content in water and bottom sediment. The highest oil content in water was found at Lubuk Gaung station 11 (0.719 ppm), western part of the research location. This might be related to the monsoon season change in which sea water current changes toward west direction during April–May 2015. Sediment oil content at Purnama station 4 (3591 ppm) was the highest. It might be attributed to the existence of industries along the coast. The high oil concentration in sediment might affect coastal ecosystems.

Introduction

Dumai water is of a semi-closed type with two tides in 24 h. The waters is one of national and international shipping lanes with an annual ship visit of around 4089–7332 times (2002–2008) with passengers of 731 188-1 012 529 (ADPEL, 2009). In addition, the water also has several industrial activities (petroleum, cement, shipping and timber) comprising processing and disposal of products from industries and households. As stated by Takarina et al. (2013), wastes are not only from sea activity, but also from coastal activity such as the surrounding settlement and industries.

Such numerous activities in Dumai coastal water including industry, shipping, the loading and unloading of goods that might deliberately dispose of waste into surrounding waters of Dumai leading to deterioration of coastal environmental condition such as capture and aquaculture fisheries, both directly and indirectly, harm biotas, human health and usability of sea ecosystem (Clark, 2001; Heath, 2000; Puig et al., 2015).

The growing industries and activities in Dumai coastal area can lead to sea pollution such as oil from transportation, spill-over, waste and storage in coastal area (Bao et al., 2014). At present, oil pollutions continue to occur in sea waters such as in Mexico Bay and Montara, in addition to tanker collision case in Mumbai (Bao et al., 2014). Dumai waters also often receive an oil spill from the tank and overflow from oil storage

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Peer review under responsibility of National Institute of Oceanography and Fisheries.

http://dx.doi.org/10.1016/j.ejar.2016.08.005

Please cite this article in press as: Ariani, F. et al., Water and sediment oil content spread in Dumai coastal waters, Riau Province, Indonesia. Egyptian Journal of Aquatic Research (2016), http://dx.doi.org/10.1016/j.ejar.2016.08.005

tanks, hence it can affect the function of the surrounding coastal environment.

Because of the covering oil layer, floating oil in waters can decrease sunrays' penetration. Photosynthesis process in euphotic zone will be hindered, breaking the food chain. The oil layer also hinders gas exchange between water and atmosphere as well as reduces the solubility of oxygen in the water that eventually makes the water unable to carry the sea's aerobic lives (IPIECA, 2000).

Such toxic oil component can adversely affect terrestrial and sea ecosystems (Shahian et al., 2012) such as reproduction process, ecosystem development, growth, and behavior of sea biotas, therefore decreasing the abundance of plankton as the food resource of fish will eventually decrease fish production as well as change flavor and aroma of fish and coral (Yamamoto et al., 2003). Organisms such as mammals, sea reptiles, and marine birds that get their foods by diving will be the most affected biota because of such oil pollution (Romero and Wikelski, 2002).

Increasing various factories, industrial, and anthropogenic activities along the time increases oil spills. Oil spills in Dumai coastal water are predicted to be accumulated because the coastal water is a semi-closed type. Such condition significantly affects the change in environmental condition around Dumai coastal area. Therefore, an analysis on oil content level in water and sediment is necessary as the goal of this research to determine the concentration of oil pollution in Dumai coastal waters.

Material and methods

Study area

This study was carried out in April–May 2015 in Dumai coastal area. Sites for the study were determined using the Purposive Random Sampling method and comprised four locations, i.e. Pangkalan Sesai (station 1,2,3) Purnama (station 4,5,6), Bangsal Aceh (station 7,8,9), and Lubuk Gaung (station 10,11,12) Administrative Villages (Fig. 1) and did two replications in each station at the same time,sampling points of which were determined using Global Positioning System (GPS).

Water and bottom sediment samples were taken out from three sites of each location. H_2SO_4 (4%) was added to water and sediment samples as preservative before the samples were put in icebox and transferred to laboratory for analysis purpose.

Sampling of oil in water and sediment

Samples of seawater surface (0–30 cm) were taken with two replications in each location of sampling at low tide using Van Dorn water sampler. As much as 1 liter water samples were inserted into the polyethylene bottle sample. Then the bottles were added two drops of concentrated H_2SO_4 (4%), labeled and put in the icebox, then iced and transported to the laboratory for analysis.

Sediment sampling is carried out once at low tide using Ekman Grab. The jaws of the grab open during descent to allow water to flow freely through, and close during ascent to reduce loss of sample during retrieval. If the jaws are not fully closed, then the sample must be discarded. The sediment can be dumped into a tray and treated as a bulk. Sediment as much as ± 250 g was put into a plastic bag and labeled, then the sample taken to the laboratory for analysis.

Oil extraction from water

Oil and fat contents in water were analyzed using the standard method (APHA, 2012). A total of 100–250 ml sea water was

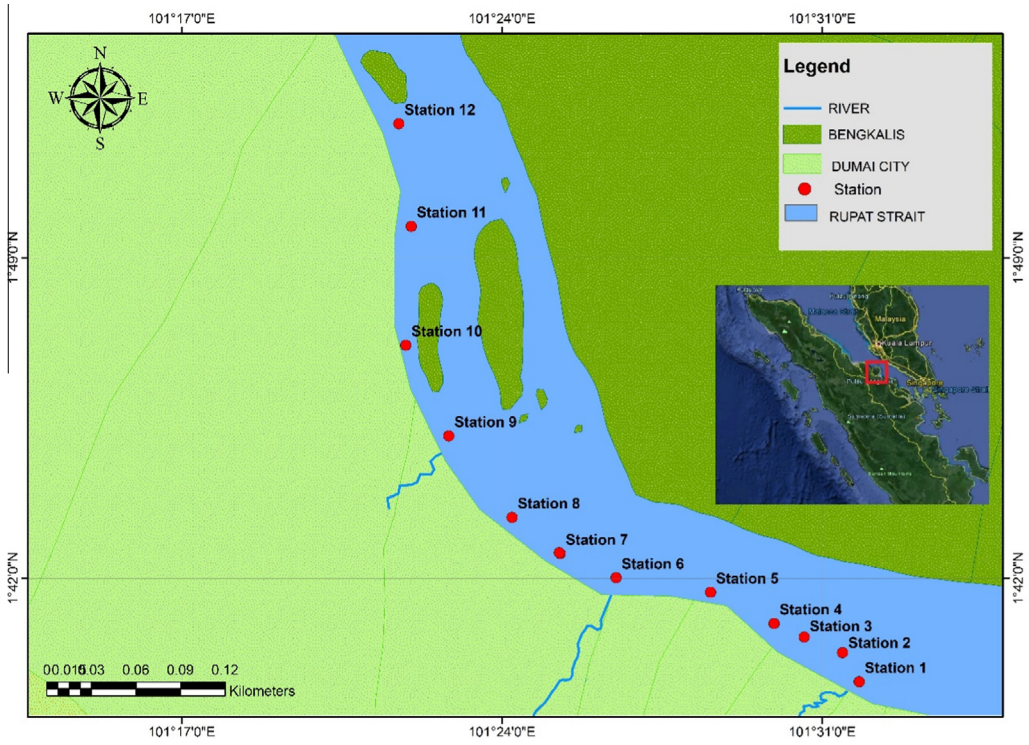


Figure 1 Map of sampling station in Dumai coastal waters.

put into a separation funnel prior to the addition of 1:1 HCl solution. 30 ml organic solvent (n-hexane) was then added and the cone was closed. The mixture was then extracted for 2 min. The solution was left to stay until 2 layers were formed. Organic phase was put in one bin and sample was repetitively extracted (2 × 30 ml). The collected organic phase was put in distillation flask through Na_2SO_4 anhydrate. The bin was then rinsed using distilled organic solvent. Once oil and pure fat formed in the first distillation flask, or condensation took place, the distillation was stopped. Distillation flask was then put in an oven for 1 h at 85 °C to make all the solvent evaporated. Distillation flask was then put in desiccator to cool it. The oil was then weighed and the concentration of which was determined.

Oil extraction from sediment

Oil and fat contents in sediment were analyzed using the Soxhlet method (Therdteppitak and Yammeng, 2003; Zhang et al., 2015). Filter paper was first weighed before 10 g sample was put above the paper and 1 g Na_2SO_4 solution was added and weighed to obtain sample weight. The flask was then also weighed to obtain empty weight. Soxhlet was first heated before the flask was put into which. Weighed sample was put in Soxhlet's extraction thimble with condenser to keep the sample cool. Extraction tube was put on Soxhlet's distillation flask with 125 ml petroleum ether solution per sample for 5 h. Extracted petroleum ether solution was then put in a measuring cup to determine as to how much the remaining solution was. The result of oil in the flask was then put in an oven for 2 h at 70 °C. The weight of the residue in the flask was then also weighed. The percentage of oil content in each sample was then converted into ppm unit.

Data analysis

Correlation between oil content in water and sediment was analyzed using Bivariate SPSS version 19.0 while oil spatial distribution in water and sediment are analyzed using ArcGis Maps 10.1 with license from Faculty of Fisheries and Marine Science, Bogor Agricultural University (FPIK IPB).

Results and discussion

Dumai coastal area is a semi-closed water with diurnal tide type (two tides a day). Pollutants that enter the water will be in static movement and cannot reach to high sea. Back and forth movement can increase the pollutant amount because it will be trapped, accumulated and sedimented on the bottom of Dumai coastal water.

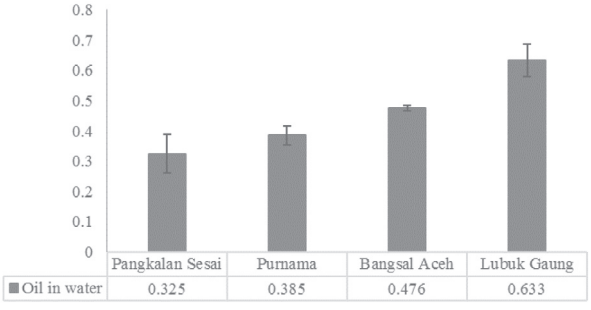
Based on Decree of Ministry of Environment No. 51 Year 2004, the oil content in the water has yet to exceed the set limit, i.e. < 5 ppm. According to criteria from National Academy of Science (NAS, 1987), oil content in sediment that is not polluted by petroleum is < 100 ppm, while the polluted one is up to 12,000 ppm.

Oil content in water and sediment showed a negative correlation each other, meaning that there is no relation between both because oil content in water will disperse and evaporate along with surface current movement, while oil contents in sediment are accumulated oil that have been suspended in water column and sedimented in water continuously.

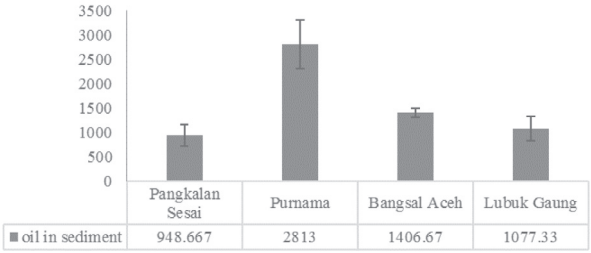
Oil contents in water (0.213–0.719 ppm) and sediment (512–1531 ppm) were significantly different from each other (Fig. 2). This difference was because it is the nature of oil to evaporate, float, and sedimented, as well as the influence of water's wave and current. The oil spill that occurred in the waters could settle down at the bottom of the water and likely cause damage to mangrove forests or other wetlands, fibrous plants and grasses as well as make the whole area unsuitable as wildlife habitat (West, 2016) and affect the photosynthesis process (Pyagbara, 2007).

There was actually no oil film on the sea water surface. Lubuk Gaung (station 10,11,12) could be regarded as west station, meanwhile Pangkalan Sesai (station 1,2,3) was east station. From Figs. 2 and 3 it could be explained that the cause of high oil content in water at Lubuk Gaung station (west station) might be attributable to the change of wind direction from west to east since April-Mei is monsoon season change from west to east season. On east season, it could be predicted, oil content in water is likely much higher at Lubuk Gaung station, since wind direction fully originates from the east, hence current moves toward the west. This is in line with Wetzel et al. (1982) who stated that basically the spread of petroleum at sea is determined by several factors, e.g. current, wave, wind, tide, and the morphology of the coastline.

Most biological communities are susceptible to the effects of oil spills, because the magnitude of exposure an animal has to oil influences the degree of harm caused (such as the amount of time the skin is in direct contact with oil, or the amount of toxic material ingested or inhaled). The more extensive the area an oil spill covers, the more difficult it becomes for animals to avoid the oil particles, and the greater the magnitude of exposure (Ridoux et al., 2004). Fig. 3 shows the high-



(a)



(b)

Figure 2 (a) Oil content in water (ppm), and (b) oil content in sediment (ppm).

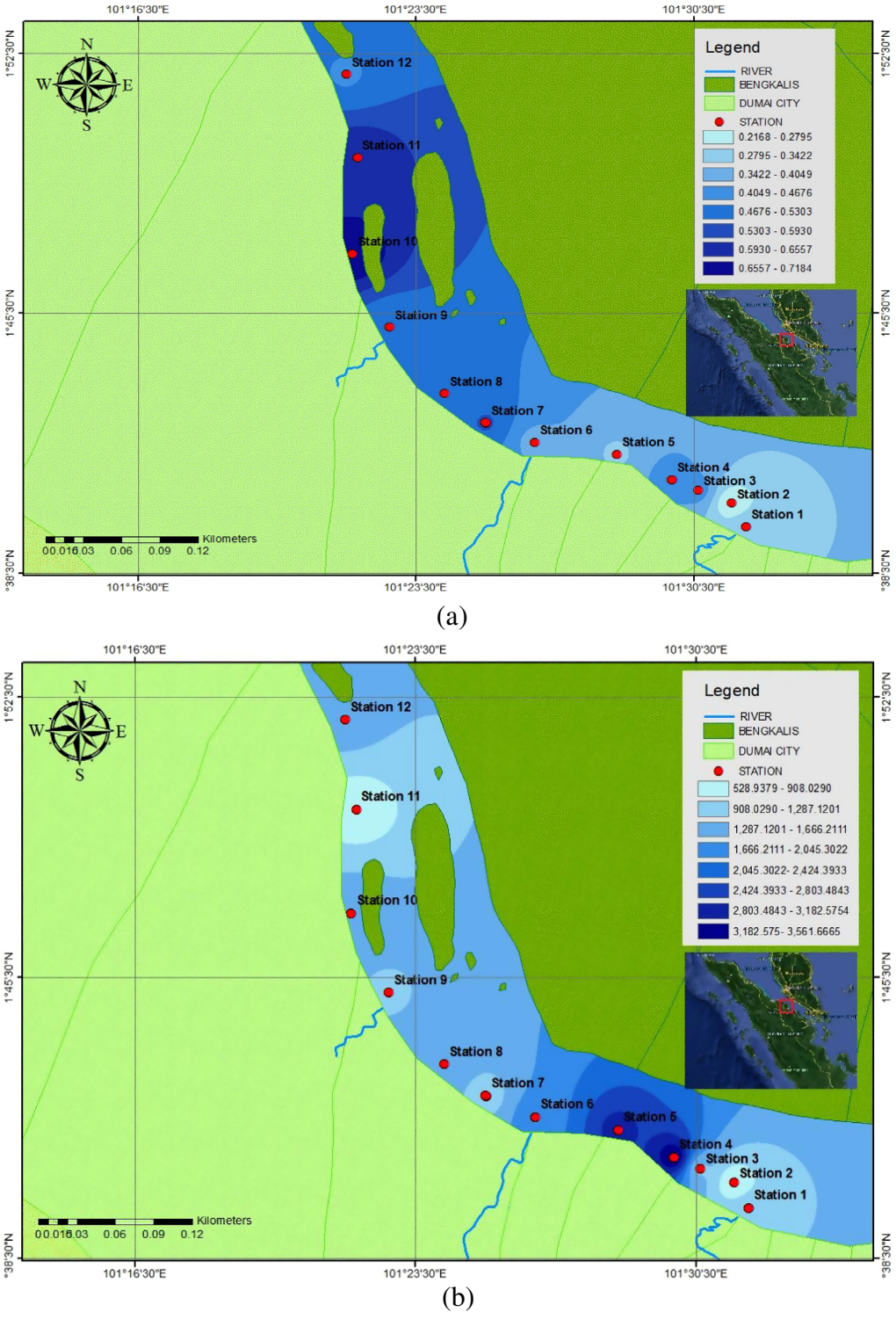


Figure 3 (a) The spread of oil content in water (ppm), and (b) the spread of oil content in sediment (ppm).

est spread level of oil content in water was at Lubuk Gaung station 10, while the lowest was at Pangkalan Sesai station 2. In addition, the highest spread level of oil content in sediment was at Purnama area station 4, while the lowest was at Pangkalan Sesai station 2. Sediment oil content spread in this regard could not be connected to monsoon season, as water oil content spread. In general, the greater the flow, the more sediment that will be conveyed. Water flow can be strong enough to suspend particles in the water column as they move downstream, or simply push them along the bottom of a waterway. Transported sediment may include mineral matter, chemicals and pollutants, and organic material with the total load includes all particles moving as bedload, suspended load, and wash load (McNally and Mehta, 2004). High oil content in

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sediment at station 4 was due to along the coast of this station, many industries locate. Low oil content in sediment at Pangkalan Sesai is presumably because there is a mangrove ecosystem at the area. As stated by Walters et al. (2008), mangrove can serve as biofilter, i.e. ability to filter, bind, and trap pollution such as excessive sediment, garbage, and other waste from households.

Sharma (2008) reported that the severity of an oil spill's impact depends on a variety of factors, including the physical properties of the oil, whether petroleum-based oils or non petroleum-based oils, and the natural actions of the receiving waters on the oil. The high oil content in the sediment of Dumai coastal area attributable to the oil accumulation process, likely causes harm to the healthiness of seabed biota such as benthic organisms Further investigation needs to be considered to convince that possible effect to the aquatic biota.

Sedimentation can occur to oil with a higher molecular weight than water or oil that was already bound to the sediment (Lee et al., 2005). Calm water particularly can increase oil distribution to deep water through sedimentation (Chen and Yapa, 2004). Oil content in water and sediment is different because of viscosity factor as well as natural forces such as the current pattern that can escalate evaporation, distribution, mixing, absorption and sedimentation of oil (Clark, 2001; Fingas and Brown, 2000).

Viscosity is a measure to limit the movement of a liquid against gravity (Chevron, 2013). Oil with low molecular weight will be first at the water surface before the oil layer becomes thin and the evaporation rate increases because of current pattern (GAO, 2007). The process of oil sedimentation tends through the food chain and the oil will be eventually deposited on the sea bottom along with the excrement of sea organisms. One of the deposition mechanisms is oil distribution to water column through suspended sediment that eventually will sink in the water (Lee et al., 2005).

Conclusion

Oil contents in Dumai coastal water were still below the threshold value set by Decree of Ministry of Environment No. 51 Year 2004, i.e. < 5 ppm, with the highest value at Lubuk Gaung station 11 (0.719 ppm). In contrast, oil contents in sediment of Dumai coastal water far exceeded the threshold set, i.e. < 100 ppm, with the highest value was at Purnama station 4 (3591 ppm). The high oil content in coastal bed sediment was as a consequence of accumulation. This might cause harm to seabed biota such as benthic organisms. Further investigation of benthic organism living in this coastal area needs to be considered to convince that possible effect.

Conflict of interest

The authors declare that there are no conflicts of interest.

Acknowledgements

This research was conducted and assisted by Laboratory of Ecology and Aquatic Environmental Management, University of Riau, and Laboratory of Agrobiology, Bogor Agricultural University.

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